

**UTILITY  
PATENT APPLICATION  
TRANSMITTAL**

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Attorney Docket No.

500414.02

First Inventor or Application Identifier

Douglas D. Do

Title

**METHOD AND APPARATUS FOR MEASURING  
FEATURES OF A SEMICONDUCTOR DEVICE**

Express Mail Label No.

EL476404902US

**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO:

Box Patent Application  
Assistant Commissioner for Patent  
Washington, D.C. 202311. ☒ General Authorization Form & Fee Transmittal  
(Submit an original and a duplicate for fee processing)2. ☒ Specification [Total Pages] **30**  
(preferred arrangement set forth below)

- Descriptive Title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. ☒ Drawing(s) (35 USC 113) [Total Sheets] **6**4. Oath or Declaration [Total Pages] **1**a. ☐ Newly executed (original or copy)b. ☒ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed)i. ☐ **DELETION OF INVENTOR(S)**  
Signed statement attached deleting  
inventor(s) named in the prior application,  
see 37 CFR 1.63(d)(2) and 1.33(b)5. ☒ Incorporation By Reference (useable if box 4b is checked)  
The entire disclosure of the prior application, from which  
a copy of the oath or declaration is supplied under Box  
4b, is considered to be part of the disclosure of the  
accompanying application and is hereby incorporated by  
reference therein.6. ☐ Microfiche Computer Program (Appendix)7. Nucleotide and Amino Acid Sequence Submission  
(if applicable, all necessary)a. ☐ Computer-Readable Copyb. ☐ Paper Copy (identical to computer copy)c. ☐ Statement verifying identity of above copies**ACCOMPANYING APPLICATION PARTS**8. ☐ Assignment Papers (cover sheet & document(s))9. ☒ 37 CFR 3.73(b)  
Statement  
(when there is an assignee)☒ Power of Attorney10. ☐ English Translation Document (if applicable)11. ☒ Information Disclosure  
Statement (IDS)/PTO-1449☐ Copies of IDS  
Citations12. ☒ Preliminary Amendment13. ☒ Return Receipt Postcard14. ☐ Small Entity  
Statement(s)☐ Statement filed in prior application,  
Status still proper and desired15. ☐ Certified Copy of Priority Document(s)  
(if foreign priority is claimed)16. ☒ Other: Certificate of Express Mail  
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17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information below and in a preliminary amendment

☐ Continuation☒ Divisional☐ Continuation-In-Part (CIP)of prior Application No. 09/083,835 Filed May 22, 1998Prior application information: Examiner Craig ThompsonGroup / Art Unit 2813☐ Claims the benefit of Provisional Application No. \_\_\_\_\_**CORRESPONDENCE ADDRESS**Dale C. Barr, Esq.  
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Respectfully submitted,

TYPED or PRINTED NAME Dale C. BarrREGISTRATION NO. 40,498

SIGNATURE

Dale C. Barr

Date

July 31, 2000

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Douglas D. Do and Jeff C. Johnson      Attorney Docket No.: 500414.02  
Filed : July 31, 2000  
Title : METHOD AND APPARATUS FOR MEASURING FEATURES OF A  
SEMICONDUCTOR DEVICE



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Respectfully submitted,

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Specification, Claims, Abstract (30 pages)  
6 Sheets of Drawings (Figures 1-6)  
Copy of Declaration  
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Preliminary Amendment  
Information Disclosure Statement and Form PTO-1449

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**Present Application:**

Applicants: Douglas D. Do and Jeff C. Johnson  
Attorney Docket No.: 500414.02  
Date : July 31, 2000  
Title : METHOD AND APPARATUS FOR MEASURING FEATURES OF A  
SEMICONDUCTOR DEVICE

**Prior Application:**

Examiner : Craig Thompson  
Art Unit : 2813  
Serial No. : 09/083,835

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**PRELIMINARY AMENDMENT**

Box Patent Application  
Assistant Commissioner of Patents  
Washington, D.C. 20231

Sir:

Prior to substantive examination, please amend the above-identified application as follows:

**In the Title:**

Amend the title of the application to read --APPARATUS FOR MEASURING FEATURES OF A SEMICONDUCTOR DEVICE-- in each place where it appears

**In the Specification:**

Amend the specification by inserting a new section before the "Technical Field" as follows:

-- CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional of pending United States Patent Application No. 09/083,835, filed May 22, 1998. --

In the Claims:

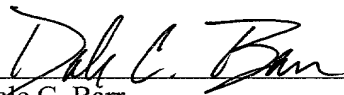
Please cancel claims 28-82.

REMARKS

Following above-noted preliminary amendments, claims 1-27 are pending in the present application. Applicants respectfully request consideration and allowance of same.

If there are any remaining matters that can be handled in a telephone conference, Applicant invites the Examiner to phone his attorney, Dale C. Barr, at (206) 903-8745.

Respectfully submitted,  
DORSEY & WHITNEY LLP

  
Dale C. Barr  
Registration No. 40,498

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N:\ip\clients\micront\500414.02\prelim amend

## METHOD AND APPARATUS FOR MEASURING FEATURES OF A SEMICONDUCTOR DEVICE

### TECHNICAL FIELD

The present invention relates to methods and devices for measuring  
5 the dimensions of features of semiconductor devices.

### BACKGROUND OF THE INVENTION

Semiconductor devices typically include a wafer comprising silicon or another semiconductor material that is etched or otherwise processed to form circuit elements. The wafer typically includes surface features, such as electrical  
10 contacts or other components, that either project upward from the surface of the wafer or form depressions or concavities in the surface of the wafer. Once the wafer has been processed, it may be desirable to examine the features under a microscope and measure the dimensions of the features to ensure that they conform to design specifications. Because the features are typically too small to  
15 resolve with visible light, which has a relatively large wavelength, the wafers are typically examined with short-wavelength electron beams under a scanning electron microscope (SEM).

One conventional method for analyzing a semiconductor wafer with a SEM includes scanning the wafer with an electron beam that is either  
20 reflected by the features, or causes the features to emit secondary electrons. The reflected or emitted electrons are received by a detector that generates a voltage signal corresponding to the rate at which the electrons are received. The voltage signal changes as a function of the orientation of the features and may be used to create an image having contrasting light and dark regions, similar in appearance  
25 to a conventional photograph. The distances between the light and dark regions may then be measured to determine the dimensions of the features.

Where the features of the semiconductor wafer are spaced relatively far apart, the electron beam may be relatively wide and may have a relatively large depth of focus, so that the electron beam may resolve features

having a wide range of heights or depths relative to the surface of the wafer. As electronic devices are made smaller and smaller, the spacing between the features on the surface of the wafer becomes smaller and smaller, and the aspect ratio of the spaces between the features increases. To adequately resolve the closely-spaced features, it has become necessary to reduce the width of the electron beam.

One drawback with conventional electron beam techniques is that, when the width of the electron beam is reduced, the depth of focus of the beam is also reduced. Accordingly, the electron beam may not be accurately focused on any relevant portion of the feature, or may be accurately focused on only one relevant portion of the feature. For example, where the beam is not accurately focused on the edges of the feature, it may be difficult to locate the edges of the feature, and may accordingly be difficult to determine the dimensions of the feature. Where the electron beam is focused on only one portion of the feature, only that portion may be accurately measured. For example, where the feature is tapered and the dimensions of the feature vary with distance from the surface of the wafer, the dimensions may only be accurately measured at the portion of the feature near the focal point of the electron beam.

Electron beams in a SEM may be automatically focused using split beam techniques or other procedures. However, a drawback with conventional SEM automatic focusing methods is that, upon reviewing the image created by the SEM, it may not be clear which portion of the feature is in focus. If the dimensions of the feature change as a function of distance from the surface of the wafer (e.g., if the feature is tapered), it may be difficult to determine which portion of the feature the resulting measurement corresponds to. The resulting measurements may therefore be inaccurate.

## SUMMARY OF THE INVENTION

The present invention is directed toward a method and apparatus for measuring the dimensions of semiconductor substrate features. The apparatus may include at least one source of electrons positioned above a stage that

supports the semiconductor device. The apparatus may further include a port surface having two ports positioned between the electron source and the support to generate two electron beams. Alternatively, the apparatus may include two electron sources to generate two electron beams. The electron beams pass  
5 through the ports and through focusing devices that may focus one electron beam on a first position relative to the semiconductor device and may focus the other electron beam at a second position relative to the semiconductor device. The support may be moved relative to the electron beams to scan the electron beams across the semiconductor device. Electrons that are either reflected or emitted by  
10 the semiconductor device when the electron beams impinge thereon may be received by detectors positioned above the semiconductor device. The detector may generate signals corresponding to the intensity of the flow of electrons it receives, and the signals may be used to generate a representation corresponding to the edges of the semiconductor device features. For example, the  
15 representation may include a graphical image or a table indicating the intensity of the reflected or emitted beams as a function of the distance traversed by the incident beam across the semiconductor device.

Alternatively, an electron beam having a first depth of focus may be scanned over the semiconductor device to create a first reflected or emitted  
20 beam. The electron beam may be re-focused to have a second depth of focus and a second reflected or emitted beam may be generated by scanning the electron beam at the second depth of focus over the semiconductor device. A user may measure the lateral dimensions of the features of the semiconductor device by analyzing, either separately or together, a graphical or tabular representation of  
25 the reflected or emitted beams.

The user may alternatively measure a height or a depth of the semiconductor device feature by analyzing signals reflected by or emitted from the device when an electron beam having a first depth of focus is focused on one portion of the feature and an electron beam having a second depth of focus is  
30 focused on another portion of the feature. The height or depth of the feature may be correlated with the difference between the two depths of focus.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic side elevation view of an apparatus in accordance with an embodiment of the invention supporting a semiconductor substrate.

5           Figure 2A is a detailed side elevation view of the semiconductor substrate of Figure 1.

Figure 2B is an image of a surface of the semiconductor substrate of Figure 2A generated by the apparatus of Figure 1.

10           Figure 2C is a graph of voltage as a function of distance obtained from the image of Figure 2B and corresponding to signals detected by a first detector and generated by an electron beam having a first depth of focus.

Figure 2D is a graph of voltage as a function of distance obtained from the image of Figure 2B and corresponding to signals detected by a second detector and generated by an electron beam having the first depth of focus.

15           Figure 2E is a graph of voltage as a function of distance obtained from the image of Figure 2B and corresponding to signals detected by the first detector and generated by an electron beam having a second depth of focus.

20           Figure 2F is a graph of voltage as a function of distance obtained from the image of Figure 2B and corresponding to signals detected by the second detector and generated by an electron beam having the second depth of focus.

Figure 3A is a graph of a combination of the voltages shown in Figures 2C and 2E.

Figure 3B is a graph of a combination of the voltages shown in Figures 2D and 2F.

25           Figure 4A is a side elevation view of another semiconductor substrate and two electron beams focused above a surface thereof.

Figure 4B is a graph of voltage as a function of distance corresponding to signals generated by an electron beam impinging on the semiconductor substrate of Figure 4A and having a first depth of focus.



Figure 4C is a graph of voltage as a function of distance corresponding to signals generated by an electron beam impinging on the semiconductor substrate of Figure 4A and having a second depth of focus.

Figure 5 is a schematic side elevation view of a portion of an apparatus having two ports in accordance with another embodiment of the invention.

Figure 6 is a side elevation schematic of a portion of an apparatus having two electron guns in accordance with still another embodiment of the invention.

## 10 DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed toward methods and apparatuses for measuring the dimensions of features of a semiconductor device. The method may include scanning the semiconductor device with an electron beam focused first at one depth and then at a second depth, or may include scanning the semiconductor device with two separate electron beams, each focused at a different depth. Many specific details of certain embodiments of the invention are set forth in the following description and in Figures 1-6 to provide a thorough understanding of such embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments and that they may be practiced without several of the details described in the following description.

Figure 1 is a schematic side elevation view of an electron beam apparatus 10 in accordance with an embodiment of the invention. The apparatus 10 includes a vacuum chamber 60 in which is housed an electron gun 30. The electron gun 30 directs an electron beam 34 toward a semiconductor device or substrate 20 positioned on a support or stage 40 beneath the electron gun. The stage 40 moves relative to the electron beam 34 such that the electron beam scans across the semiconductor substrate 20. Electrons reflected or emitted by the semiconductor substrate 20 are received by two detectors 50 (shown as 50a and 50b). The detectors 50 transmit to a controller 70 and a processor 73 signals

corresponding to the strength or intensity of the reflected beam. The data generated by the processor 73 are then analyzed to determine the dimensions of features on the semiconductor substrate 20.

The vacuum chamber 60 is coupled to two vacuum sources 61 (shown as 61a and 61b). One vacuum source 61a evacuates the main portion of the vacuum chamber 60 and the other vacuum source 61b evacuates a loading bay 62 connected to the vacuum chamber 60. Semiconductor substrates 20 may be loaded in the loading bay 62 while it is at atmospheric pressure and a vacuum is maintained in the vacuum chamber 60. The vacuum source 61b is then activated to lower the pressure in the loading bay 62 until it matches the vacuum pressure in the vacuum chamber 60, at which point the substrate 20 is moved into the vacuum chamber 60. Accordingly, the vacuum pressure in the vacuum chamber 60 may be maintained at less than atmospheric levels while the semiconductor substrate 20 is moved into and out of the vacuum chamber.

The semiconductor substrate 20 is transported from the loading bay 62 into the vacuum chamber 60 on the stage 40. A drive unit 42 is coupled to the stage 40 and moves the stage in three orthogonal directions, as indicated by arrows X, Y, and Z. The stage 40 includes a sensor 41 that tracks the location of the stage as it moves, and transmits to the controller 70 signals corresponding to the location of the stage. A light source 43 may be positioned above the stage 40 to separately measure the vertical position of the stage 40 by generating a light beam 44 that is reflected from the stage 40 and/or the semiconductor substrate 20 and received by a light detector 45. An optical microscope 63 may also be positioned above the stage 40 for visual inspection of the stage 40 and the semiconductor substrate 20.

The electron beam 34 emitted by the electron gun 30 passes through a condenser lens 31 that concentrates the electron beam 34, then through an aperture 32, and through an objective lens 33 that further concentrates the electron beam. The lenses 31 and 33 may include charged plates or other known means for focusing the electron beam 34. In one embodiment, the electron beam 34 strikes the semiconductor substrate 20 and is reflected in several directions.

In another embodiment, the electron beam 34 strikes the semiconductor substrate 20 which in turn emits secondary electrons in several directions. The term secondary beam is used herein to refer to electron beams reflected by and/or emitted by the semiconductor substrate 20. For purposes of clarity, two  
 5 secondary beams 51 (shown as 51a and 51b) are shown in Figure 1, though it will be understood that the secondary electrons may form other beams that travel in directions other than those shown in Figure 1.

In one embodiment, the two electron detectors 50 are positioned above the stage 40 to receive the two secondary beams 51. Other embodiments  
 10 may include a greater or lesser number of electron detectors 50. In the embodiment shown in Figure 1, the electron detectors 50 are positioned on opposite sides of the semiconductor substrate 20. Accordingly, a right electron detector 50a will tend to receive the right secondary beam 51a, which includes electrons emanating from rightward facing features, and the left electron detector  
 15 50b will tend to receive the left secondary beam 51b, which includes electrons emanating from leftward facing features, as will be discussed in greater detail below with respect to Figure 2A.

When the secondary beams 51 strike the electron detectors 50, they generate electrical signals that are transmitted to the controller 70. The signals  
 20 proceed from the controller 70 to the processor 73 where they are reduced to human readable representations, as will be discussed in greater detail below with reference to Figures 2B-2F. The representations may be displayed on a display 71 and/or may be printed on a printer 72, and/or may be stored on an electronic storage device 74 for subsequent processing.

25 The processor 70 is also coupled to the electron gun 30, the lenses 31 and 33, the vacuum sources 61, the loading bay 62, and the drive unit 42. Accordingly, the controller 70 may control the motion of the semiconductor substrate 20 into and out of the vacuum chamber 60 and the motion of the semiconductor substrate 20 and the electron beam 34 relative to each other.

30 In operation, the controller 70 controls the electron gun 30 and the lenses 31 and 33 to produce an electron beam 34 having a selected depth of

focus. The drive unit 42 moves the stage 40 into position beneath the electron gun 30 and moves the stage in the Z direction so that the electron beam 34 is focused on a selected portion of the semiconductor substrate 20. The drive unit 42 then moves the stage 40 in the X and Y directions to scan the electron beam 34 in a series of parallel paths across the semiconductor substrate 20, producing the secondary beams 51 that are received by the electron detectors 50 and processed by the processor 73.

Figure 2A is a side elevation view of an example of the semiconductor substrate 20. In the embodiment shown in Figure 2A, the semiconductor substrate 20 has a top surface 22, a bottom surface 27, and two raised features 21 projecting above the top surface 22. In other embodiments, the semiconductor substrate 20 may have more than two features and/or may have features that are recessed from the top surface 22. Each feature 21 has an upper surface 23, upper corners 25 (shown as 25a and 25b), side surfaces 24 (shown as 24a and 24b), and lower corners 26 (shown as 26a and 26b).

The semiconductor substrate may be scanned by a first electron beam 34' having a depth of focus  $D_1$  centered on the upper corners 25 of the features 21, and by a second electron beam 34'' having a depth of focus  $D_2$  centered on the lower corners 26 of the feature. When the first electron beam 34' scans across the semiconductor substrate 20, the detectors 50 (Figure 1) generate a series of electrical signals corresponding to the secondary beams 51 (Figure 1). Figure 2B is a plan view of a two-dimensional image 52 generated from the signals and having a pattern of contrasting regions corresponding to the features 21 and the top surface 22 of the semiconductor substrate 20. As shown in Figure 2B, dark regions 54 correspond to the substrate top surface 22, light regions 53 correspond to the side surfaces 24 of the features 21, and gray regions 55 correspond to the upper surfaces 23 of the features.

In one embodiment, the data for a given portion of the image 52 may be collapsed to produce a single graph of voltage (corresponding to the intensity of the secondary beam 51 (Figure 1)) as a function of distance in the X direction. For example, Figure 2C is a graph of a voltage signal 56a' as a

function of distance in the X direction, as detected by the right electron detector 51a (Figure 1). The signal 56a' has major spikes corresponding to the right upper corners 25a (facing toward the right detector 51a), and minor spikes corresponding to the left upper corners 25b (facing away from the right detector 51a). Figure 2D is a similar graph of a voltage signal 56b' corresponding to the reflected intensity of the secondary beam 50b (Figure 1) as detected by the left detector 51b (Figure 1). A user may measure a width  $W_1$  of the feature upper surface 23 by measuring the corresponding distance between the peaks shown in Figures 2C and/or 2D. In one embodiment, the user may use the voltage signal that most sharply defines the region of interest. For example, the user may use the voltage signal 56a' to accurately locate the right upper corners 25a and the voltage signal 56b' to accurately locate the left upper corners 25b.

In a manner similar to that discussed above with reference to Figures 2B-2D, the user may then generate another image (not shown) corresponding to electrons received from the semiconductor substrate 20 when it is impinged by the second electron beam 34''. The data corresponding to the image may be collapsed to produce a voltage signal 56a'' (shown in Figure 2E) corresponding to the secondary beam 51a received by the right electron detector 50a, and a voltage signal 56b'' (shown in Figure 2F) corresponding to the secondary beam 51b received by the left electron detector 50b. A width  $W_2$  of the base of feature 21 may be measured from the traces 56a'' and 56b'', in a manner similar to that discussed above with reference to Figures 2C-2D.

In another aspect of this embodiment, the voltage signals 56a' and 56a'' may be combined to form a single voltage signal 56a corresponding to the signal received by the right detector 50a (Figure 1), as shown in Figure 3A. Similarly, the voltage signals 56b' and 56b'' may be combined to form a single trace 56b corresponding to the signal received by the left detector 50b (Figure 1), as shown in Figure 3B. The traces 56a and 56b may more clearly indicate the feature dimensions  $W_1$  and  $W_2$  in a single graph. In yet a further embodiment, the traces 56a and 56b may also be combined to form a single, composite signal.

Returning to Figure 2A, other representations or combinations of representations may be used to determine the dimensions of the features 21 in other embodiments, so long as more than one electron beam is used to generate the representation. For example, in one such embodiment, a tabular representation of the voltage generated by the secondary beams 51 (Figure 1) as a function of distance may be generated and analyzed to determine the dimensions of the features 21. In another embodiment, more than two electron beams 34, each having a different depth of focus, may be used to determine the width of a feature 21 at more than two distances from the top surface 22 of the semiconductor substrate 20. In still another embodiment, the user may analyze the data to determine dimensions other than the width of the feature 21. For example, in one such embodiment, the data may be used to determine a dimension of the feature 21 in the Y direction (Figure 2B). In another such embodiment, the user may determine the height H of the feature 21 by taking the difference in distance in the Z direction between the focal points of the electron beams 34' and 34'' and correlating the difference with corresponding known feature heights.

An advantage of the method and apparatus discussed above with reference to Figures 1-3B is that an electron beam 34 may be focused to have two different depths of focus corresponding to different heights of the feature 21 on the surface of the semiconductor substrate 20. Accordingly, the lateral dimensions of the feature 21 at each height may be determined, even if the dimensions are different at each height. Another advantage of the method and apparatus is that an electron beam 34 having a relatively small depth of focus may be used to resolve different portions of the feature in sharp focus by first scanning the feature with the electron beam focused at one depth and then scanning the same feature with the electron beam focused at a different depth. Yet a further advantage is that the height or depth of the feature may be determined by scanning the feature with an electron beam or beams 34 having different depths of focus.

Figure 4A is a side view of a semiconductor substrate 120 having a top surface 122 and raised features 121 with vertical side surfaces 124 (shown as 124a and 124b). An electron beam 134'' having a depth of focus  $D_3$  centered between the upper corners 125 (shown as 125a and 125b) and the lower corners 126 (shown as 126a and 126b) of the features 121 may be scanned over the semiconductor substrate 120. Figure 4B is a graph of the resulting voltage signal 156a'', as detected by the right detector 50a (Figure 1). As shown in Figure 4B, the voltage signal 156a'' has relatively ill-defined peaks. When the focal point is shifted either upward or downward, the peaks may be more sharply defined. For example, the focal point may be shifted upward, such that an electron beam 134' has a depth of focus  $D_4$  approximately centered at the upper corners 125a of the features 121. The resulting voltage signal 156a', shown in Figure 4C, has more sharply defined peaks that more clearly indicate the corners 125 and 126 of the feature 121.

Referring to Figures 4A-4C, a method in accordance with one embodiment of the invention may include selecting a voltage signal that has a more sharply defined change in voltage as a function of distance, and measuring the width  $W_1$  between peaks of the selected signal. In one aspect of this embodiment, where the width  $W_1$  is the same at both the upper and lower corners 125 and 126, the selected signal may correspond to a depth of focus centered on either the upper corners 125 or the lower corners 126. The signal having the more sharply defined change in voltage as a function of distance may be selected manually by visually inspecting the traces 156a' and 156a'' or automatically, for example with software that determines the slope and location of the spikes shown in Figures 4B-4C. Once the desired depth of focus has been established, any remaining unscanned portions of the semiconductor substrate 120, or other substrates, may be scanned with an electron beam having the same depth of focus.

An advantage of the method discussed above with reference to Figures 4A-4C when compared to the method discussed above with reference to Figures 2A-2F is that it may be less time-consuming to focus the electron beam

sharply at a single location. This method may be particularly applicable where the feature has a constant width as a function of distance from the top surface 122 of the substrate 120. Conversely, an advantage of the method discussed above with reference to Figures 2A-2F is that by sharply focusing an electron beam on  
 5 both the substrate top surface 122 and the feature upper surface 123, the dimensions of a feature may be readily determined, even if the feature has different widths as a function of distance from the top surface.

Figure 5 is a schematic side elevation view of an apparatus 210 in accordance with another embodiment of the invention. The apparatus 210  
 10 includes a vacuum chamber 260 having an electron gun 230 positioned above the stage 240 on which the substrate 20 is positioned. The electron gun 230 may be coupled to a drive unit 235 that moves the electron gun in the Z direction. A position detector 237 may be coupled to the electron gun 230 to track the movement of the electron gun. Electrons generated by the electron gun 230 pass  
 15 through the condenser lens 231 and through two apertures or ports 232 (shown as 232a and 232b) in a port surface 236 to form two electron beams 235 (shown as 235a and 235b). The electron beams 235 are focused by corresponding objective lenses 233 (shown as 233a and 233b) before impinging on the semiconductor substrate 20.

20 In one aspect of this embodiment, the position of the substrate 20 relative to the focal points of the electron beams 235 may be changed by manipulating the lenses 231 and 233. In another aspect of this embodiment, the position of the semiconductor substrate 20 may be changed by moving the stage 240 relative to the electron gun 230. In yet another aspect of this embodiment,  
 25 the relative position between the semiconductor substrate 20 and the focal points of the electron beams 235 may be changed by moving the electron gun 230 along the Z axis with the drive unit 235.

Each of the electron beams 235 may be focused at a different point along the Z axis. In one embodiment, the aperture 235b may be blocked and the  
 30 semiconductor substrate 20 may be scanned by the one electron beam 235a. The aperture 235b may then be uncovered and the aperture 235a blocked and the



semiconductor substrate 20 may be scanned with the other electron beam 235b. In another embodiment, the semiconductor substrate 20 may be scanned by both electron beams 235a and 235b simultaneously to produce a composite image and voltage signals similar to those shown in Figures 3A and 3B. Accordingly, one  
5 advantage of the apparatus 210 shown in Figure 5 is that it may be less time-consuming to scan the semiconductor substrate 20 simultaneously with two electron beams, each having a different depth of focus. Conversely, an advantage of the device 10 shown in Figure 1 is that for some semiconductor substrates 20, it may be more convenient to analyze separate images  
10 corresponding to electron beams having different depths of focus that it is to analyze the composite image and voltage signals data discussed above with reference to Figure 5.

Figure 6 is a schematic side elevation view of an apparatus 310 in accordance with another embodiment of the invention having two electron  
15 guns 330 (shown as 330a and 330b) positioned above a stage 340 and the semiconductor substrate 20. The apparatus 310 further includes two corresponding condenser lenses 331 (shown as 331a and 331b), two apertures or ports 332 (shown as 332a and 332b), and two objective lenses 333 (shown as 333a and 333b) to focus the corresponding electron beams 335 (shown as 335a  
20 and 335b) on the semiconductor substrate 20. The apparatus 310 may be operated in a manner generally similar to that discussed above with reference to Figure 5. One advantage of the apparatus 310 shown in Figure 6, when compared to the apparatus 210 shown in Figure 5, is that the electron beams 335a and 335b may be individually controlled because they are emitted from separate  
25 electron guns 330a and 330b, respectively. Conversely, an advantage of the apparatus 210 shown in Figure 5 is that the single electron gun 230 may be less expensive to install and maintain than the dual electron guns 330a and 330b shown in Figure 6.

From the foregoing it will be appreciated that, although specific  
30 embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit

and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

## CLAIMS

1. An apparatus for determining a dimension of a feature of a semiconductor device, comprising:

at least one source of electrons;

a focusing device positioned proximate to the source of electrons to focus electrons emitted by the source and form an electron beam, the focusing device focusing the electron beam to have first and second depths of focus and form at least one representation of the semiconductor device corresponding to electrons focused at the first and second depths of focus and impinging on the semiconductor device;

a support aligned with the electron beam and having a support surface to engage the semiconductor device and support the semiconductor device, one of the electron beam and the support being movable relative to the other of the electron beam and the support.

2. The apparatus of claim 1 wherein the support is movable relative to the source in a direction generally transverse to the electron beam.

3. The apparatus of claim 1 wherein the support is movable relative to the source in a direction generally aligned with an axis of the electron beam.

4. The apparatus of claim 1, further comprising a first detector spaced apart from the support to receive a first flow of electrons from the semiconductor device and generate a first signal corresponding thereto, and a second detector spaced apart from the support to receive a second flow of electrons from the semiconductor device and generate a second signal corresponding thereto.

5. The apparatus of claim 4, further comprising a third detector operatively coupled to one of the support and the source to detect movement of the one of the support and the source, the third detector generating a third signal corresponding to movement detected thereby.

6. The apparatus of claim 5, further comprising a memory device coupled to at least one of the detectors to store the signal generated by the detector.

7. The apparatus of claim 5, further comprising a display coupled to the detectors to graphically display a voltage generated by the first and second electron flows as a function of the movement detected by the third detector.

8. The apparatus of claim 5, further comprising a printing device coupled to the detectors to print a representation of a voltage generated by the first and second flows of electrons as a function of the movement detected by the third sensor.

9. The apparatus of claim 1 wherein the source of electrons is a first source, the electron beam corresponding thereto is a first electron beam focused at the first depth of focus, and the focusing device is a first focusing device, further comprising:

a second source of electrons spaced apart from the first source of electrons; and

a second focusing device positioned proximate to the second source of electrons to focus electrons emitted by the second source and form a second electron beam, the second focusing device focusing the second electron beam to have the second depth of focus simultaneously with the first focusing device focusing the first electron beam to have the first depth of focus.

10. The apparatus of claim 1 wherein the focusing device is a first focusing device and the electron beam is a first electron beam, further comprising:

a port surface positioned intermediate the source and the first focusing device and having first and second ports therethrough, the first port being positioned proximate to the source to form the first electron beam, the second port spaced apart from the first port to form a second electron beam; and

a second focusing device positioned proximate to the second port to focus the second electron beam to have the second depth of focus simultaneously with

the first focusing device focusing the first electron beam to have the first depth of focus.

11. The apparatus of claim 1 wherein the focusing device focuses the electron beam to have the first depth of focus prior to focusing the electron beam to have the second depth of focus.

12. An apparatus for determining a dimension of a feature of a semiconductor device, comprising:

a source of electrons;

a port surface having a first and second ports therethrough, the first port being positioned proximate to the source to form a first electron beam when electrons pass therethrough, the second port spaced apart from the first port to form a second electron beam when electrons pass therethrough;

a first focusing device positioned proximate to the first port and adjacent the first electron beam to focus the first electron beam on a first position;

a second focusing device positioned proximate to the second port and adjacent the second electron beam to focus the second electron beam on a second position that is different from the first position; and

a support aligned with the first and second ports and having a support surface to engage the semiconductor device and support the semiconductor device at the first and second positions, one of the support and the source being movable relative to the other of the support and the source.

13. The apparatus of claim 12 wherein the support is movable relative to the source in a direction generally transverse to at least one of the first and second electron beams.

14. The apparatus of claim 12 wherein the support is movable relative to the source in a direction generally aligned with an axis of at least one of the first and second electron beams.

15. The apparatus of claim 12, further comprising a first detector spaced apart from the support to receive a first flow of electrons from the semiconductor device and generate a first signal corresponding thereto, and a second detector spaced apart from the support to receive a second flow of electrons from the semiconductor device and generate a second signal corresponding thereto.

16. The apparatus of claim 15, further comprising a third detector operatively coupled to one of the support and the source to detect movement of the one of the support and the source, the third detector generating a third signal corresponding to movement detected thereby.

17. The apparatus of claim 16, further comprising a memory device coupled to at least one of the detectors to store the signal generated by the detector.

18. The apparatus of claim 16, further comprising a display coupled to the detectors to graphically display a voltage generated by the first and second electron flows as a function of the movement detected by the third detector.

19. The apparatus of claim 16, further comprising a printing device coupled to the detectors to print a representation of a voltage generated by the first and second flows of electrons as a function of the movement detected by the third sensor.

20. An apparatus for determining a dimension of a semiconductor device feature, comprising:

first and second sources of electrons;

a first focusing device positioned proximate to the first source of electrons to focus a first electron beam emitted from the first source;

a second focusing device positioned proximate to the second source of electrons to focus a second electron beam emitted from the second source; and

a support aligned with the first and second focusing devices and configured to engage the semiconductor device, one of the support and the sources of

electrons being movable relative to the other of the support and the sources of electrons.

21. The apparatus of claim 20 wherein the support is movable relative to the sources of electrons in a direction generally transverse to at least one of the first and second electron beams.

22. The apparatus of claim 20 wherein the support is movable relative to the sources of electrons in a direction generally aligned with an axis of at least one of the first and second electron beams.

23. The apparatus of claim 20, further comprising a first detector spaced apart from the support to receive a first flow of electrons from the semiconductor device and generate a first signal corresponding thereto, and a second detector spaced apart from the support to receive a second flow of electrons reflected from the semiconductor device and generate a second signal corresponding thereto.

24. The apparatus of claim 23, further comprising a third detector operatively coupled to one of the support and the sources to detect movement of the one of the support and the sources, the third detector generating a third signal corresponding to movement detected thereby.

25. The apparatus of claim 24, further comprising a memory device coupled to at least one of the detectors to store the signal generated by the detector.

26. The apparatus of claim 24, further comprising a display coupled to the detectors to graphically display a strength of the first and second electron flows as a function of the movement detected by the third detector.

27. The apparatus of claim 24, further comprising a printing device coupled to the detectors to print a representation of a strength of the first and second flows of electrons as a function of the movement detected by the third detector.

28. A method for determining a dimension of a semiconductor device feature, comprising:

positioning a portion of the feature at a first axial distance from a focal point of an electron beam;

detecting a first flow of electrons corresponding to the electron beam and received from the feature when the electron beam impinges on the feature and the portion of the feature is spaced apart from the focal point by the first distance;

effectively moving at least one of the feature and the focal point of the electron beam to position the portion of the feature at a second axial distance from the focal point of the electron beam;

detecting a second flow of electrons corresponding to the electron beam and received from the feature when the electron beam impinges on the feature and the portion of the feature is spaced apart from the focal point by the second distance; and

analyzing the first and second flows to determine a dimension of the feature.

29. The method of claim 28 wherein the first flow of electrons is a portion of the electron beam reflected by the feature and the step of detecting the first flow includes detecting the reflected portion of the electron beam.

30. The method of claim 28 wherein the first flow of electrons is emitted by the feature when the electron beam impinges thereon, and the step of detecting the first flow includes detecting the emitted electrons.

31. The method of claim 28 wherein the step of moving at least one of the feature and the focal point comprises moving the feature relative to the focal point along an axis of the electron beam.

32. The method of claim 28 wherein the step of moving at least one of the feature and the focal point includes moving a source of the electron beam relative to the feature along an axis of the electron beam.



33. The method of claim 28 wherein the step of moving at least one of the feature and the focal point comprises focusing the electron beam to have the focal point spaced apart from the feature by the second distance.

34. The method of claim 28, further comprising moving one of the feature and the electron beam transverse to an axis of the electron beam.

35. The method of claim 28, further comprising translating one of the feature and the electron beam along a first path transverse to an axis of the electron beam when the portion of the feature is spaced apart from the focal point by the first distance and translating one of the feature and the electron beam along a second path transverse to the axis of the electron beam when the portion of the feature is spaced apart from the focal point by the second distance.

36. The method of claim 35 wherein the first path is generally the same as the second path.

37. The method of claim 35 wherein the step of analyzing includes forming a first representation of a voltage corresponding to the first flow of electrons as a function of a first transverse distance translated by the one of the focal point and the feature along the first path, the step further including forming a second representation of a voltage corresponding to the second flow of electrons as a function of a second transverse distance translated by the one of the focal point and the feature along the second path, the step still further including selecting one of the first and second representations.

38. The method of claim 37 wherein the step of selecting includes visually accessing the first and second representations.

39. The method of claim 37 wherein the step of selecting includes using a computer program to select the one of the first and second representations.

40. The method of claim 37 wherein the step of forming the first representation includes forming a graphical representation.

41. The method of claim 37 wherein the step of forming the first representation includes forming a tabular representation.

42. The method of claim 37 wherein the first representation has a first change in voltage corresponding to an edge of the feature and the second representation has a second change in voltage corresponding to the edge of the feature and the step of analyzing the first and second flows includes selecting the one of the first and second representations having a greater change in voltage per unit of transverse distance.

43. The method of claim 42, further comprising scanning a remaining portion of the semiconductor device with the semiconductor device positioned at the one of the first and second axial distances that corresponds to the selected one of the first and second representations.

44. The method of claim 37, further comprising:  
storing data corresponding to an intensity of the first flow of electrons as a function of a first transverse distance translated by the one of the focal point and the feature along the first path; and

storing data corresponding to an intensity of the second flow of electrons as a function of a second transverse distance translated by the one of the focal point and the feature along the second path.

45. The method of claim 35 wherein the step of analyzing includes forming a first representation of a voltage corresponding to the first flow of electrons as a function of a first transverse distance translated by the one of the focal point and the feature along the first path, the step further including forming a second representation of a voltage corresponding to the second flow of electrons as a function

of a second transverse distance translated by the one of the focal point and the feature along the second path, the step still further including combining the first and second representations.

46. The method of claim 28 wherein the step of analyzing the first and second flows includes determining a lateral dimension of the feature.

47. The method of claim 28 wherein the step of analyzing the first and second flows includes determining a vertical dimension of the feature.

48. The method of claim 47 wherein the step of moving at least one of the feature and the focal point includes

measuring a first position of the focal point when the feature is spaced apart from the focal point by the first distance,

focusing the electron beam to have the focal point spaced apart from the feature by the second distance, and

measuring a second position of the focal point when the feature is spaced apart from the focal point by the second distance.

49. A method for measuring a dimension of a semiconductor device feature, comprising:

moving one of a first electron beam and the feature transversely relative to the other of the first electron beam and the feature, the first electron beam impinging on the feature and having a first depth of focus centered at a first point;

receiving a first flow of electrons from the feature corresponding to the first electron beam;

moving one of a second electron beam and the feature transversely relative to the other of the second electron beam and the feature, the second electron beam impinging on the feature and having a second depth of focus centered at a second point, the second depth of focus being different from the first depth of focus;

receiving a second flow of electrons from the feature corresponding to the second electron beam; and

analyzing the first and second flows to determine a dimension of the feature.

50. The method of claim 49 wherein the first flow of electrons is a portion of the first electron beam reflected by the feature and the step of receiving the first flow includes receiving the reflected portion of the first electron beam.

51. The method of claim 49 wherein the first flow of electrons is emitted by the feature when the first electron beam impinges thereon, and the step of receiving the first flow includes receiving the emitted electrons.

52. The method of claim 49 wherein the step of analyzing includes forming a first representation of an intensity of the first flow of electrons as a function of a first transverse distance moved by the one of the first electron beam and the feature, the step further including forming a second representation of an intensity of the second flow of electrons as a function of a second transverse distance moved by the one of the second electron beam and the feature, the step still further including selecting one of the first and second representations.

53. The method of claim 52 wherein the step of forming a first representation of an intensity of the first flow of electrons includes forming a representation of a voltage corresponding to the first flow of the electrons.

54. The method of claim 52 wherein the first representation has a first change in intensity corresponding to an edge of the feature and the second representation has a second change in intensity corresponding to the edge of the feature and the step of analyzing the first and second flows includes selecting the one of the first and second representations having a greater change in intensity per unit of transverse distance moved.

55. The method of claim 49 wherein the step of analyzing includes forming a first representation of an intensity of the first flow of electrons as a function of a first transverse distance moved by the one of the first electron beam and the feature, the step further including forming a second representation of an intensity of the second flow of electrons as a function of a second transverse distance moved by the one of the second electron beam and the feature, the step still further including combining the first and second representations to form a composite representation.

56. The method of claim 49 wherein the step of moving one of the first electron beam and the feature is simultaneous with the act of moving one of the second electron beam and the feature.

57. The method of claim 49 wherein the step of moving one of the first electron beam and the feature occurs before the act of moving one of the second electron beam and the feature.

58. The method of claim 49, further comprising emitting the first and second electron beams sequentially from a single port.

59. The method of claim 49, further comprising emitting the first electron beam from a first port and simultaneously emitting the second electron beam from a second port.

60. The method of claim 49, further comprising emitting the first and second electron beams from a single electron gun.

61. The method of claim 49, further comprising emitting the first electron beam from a first electron gun and emitting the second electron beam from a second electron gun.

62. The method of claim 49, further comprising:

storing data corresponding to an intensity of the first flow of electrons as a function of a first transverse distance moved by the one of the first electron beam and the feature; and

storing data corresponding to an intensity of the second flow of electrons as a function of a second transverse distance moved by the one of the second electron beam and the feature.

63. The method of claim 49 wherein the step of analyzing the first and second flows includes determining a lateral dimension of the feature.

64. The method of claim 49 wherein the step of analyzing the first and second flows includes determining a vertical dimension of the feature.

65. The method of claim 64 wherein the step of determining the vertical dimension includes determining a distance between the first and second points, the first electron beam having the first depth of focus centered at the first point, the second electron beam having the second depth of focus centered at the second point.

66. A method for determining a width of a feature of a semiconductor device having a first surface and a second surface opposite the first surface, the feature having two first edges spaced apart from one of the first and second surfaces by a first distance and two second edges spaced apart from one of the first and second surfaces by a second distance, the method comprising:

focusing a first electron beam to have a first depth of focus approximately centered at the first distance and receiving a first flow of electrons from the feature corresponding to the first electron beam;

focusing a second electron beam to have a second depth of focus centered at a third distance different than the first and second distances and receiving a

second flow of electrons from the feature corresponding to the second electron beam;  
and

measuring a distance between the first edges of the feature by moving one of the feature and the first electron beam relative to the other of the feature and the first electron beam transverse to an axis of the first electron beam along a transverse path while the first electron beam has a depth of focus approximately centered at the first distance.

67. The method of claim 66, further comprising emitting the first and second electron beams sequentially from a single source.

68. The method of claim 66, further comprising emitting the first electron beam from a first port and simultaneously emitting the second electron beam from a second port.

69. The method of claim 66 wherein the step of focusing the first electron beam is simultaneous with the step of focusing the second electron beam.

70. The method of claim 66 wherein the step of focusing the first electron beam occurs after the step of focusing the second electron beam.

71. The method of claim 66 wherein the step of measuring the distance between the first edges includes detecting an intensity of the first flow of electrons as a function of a transverse distance moved by the one of the first electron beam and the feature and determining a distance between changes in the intensity of the first flow.

72. The method of claim 66, further comprising storing data corresponding to the intensity of the first flow of electrons as a function of a transverse distance moved by the one of the first electron beam and the feature.

73. A method for determining a width of a feature of a semiconductor device having a first surface and a second surface opposite the first surface, the feature having first edges spaced apart from one of the first and second surfaces by a first distance and second edges spaced apart from one of the first and second surfaces by a second distance, the method comprising:

focusing a first electron beam to have a first depth of focus approximately centered at the first distance and receiving a first electron flow from the feature corresponding to the first electron beam;

focusing a second electron beam to have a second depth of focus approximately centered at the second distance and receiving a second electron flow from the feature corresponding to the second electron beam, the second distance being different from the first distance;

measuring the first electron flow to form a first measurement;

measuring the second electron flow to form a second measurement;

combining the first and second measurements to form a composite measurement; and

analyzing the composite measurement to determine a width of the feature.

74. The method of claim 73, further comprising moving one of the feature and the first electron beam relative to the other transverse to an axis of the first electron beam along a first transverse path and moving one of the feature and the second electron beam relative to the other transverse to an axis of the second electron beam along a second transverse path.

75. The method of claim 74 wherein the composite measurement includes a voltage generated by the first electron flow as a function of a distance moved by the one of the first electron beam and the feature along the first transverse path, the composite measurement further including a voltage generated by the second electron flow as a function of a distance moved by the one of the second electron beam and the feature along the second transverse path, and the step of analyzing the



composite measurement includes measuring a distance between changes in the voltage generated by one of the electron flows that correspond to the first edges.

76. The method of claim 75 wherein the step of analyzing the composite measurement includes measuring a first distance between changes in the voltage generated by the first electron flow that correspond to the first edges and measuring a second distance between changes in the voltage generated by the second electron that correspond to the second edges.

77. The method of claim 73 wherein the step of focusing the first electron beam is simultaneous with the step of focusing the second electron beam.

78. The method of claim 73 wherein the step of focusing the first electron beam occurs after the step of focusing the second electron beam.

79. The method of claim 73, further comprising emitting the first and second electron beams sequentially from a single port.

80. The method of claim 73, further comprising emitting the first electron beam from a first port and simultaneously emitting the second electron beam from a second port.

81. The method of claim 73 wherein the first electron flow is a portion of the first electron beam reflected by the feature and the step of measuring the first electron flow includes measuring the reflected portion of the first electron beam.

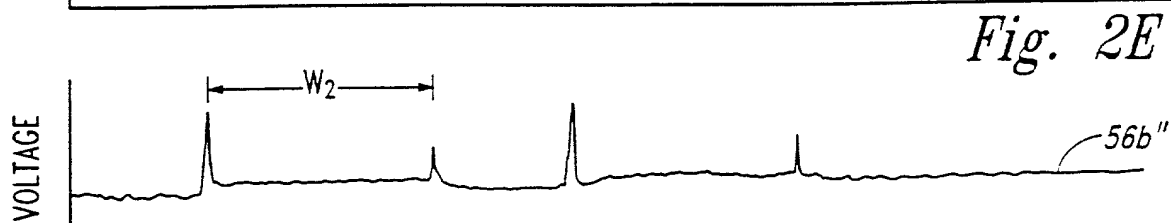
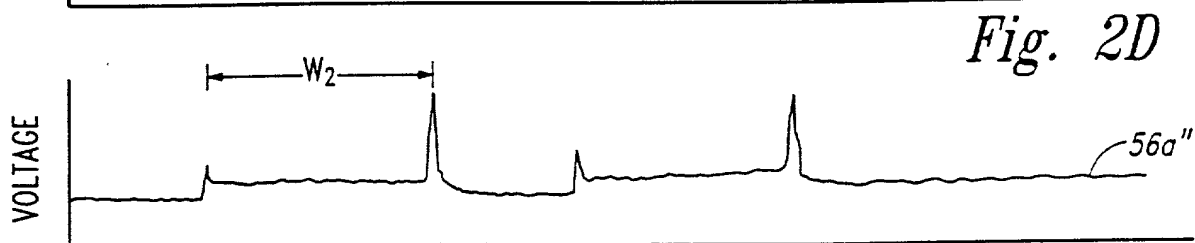
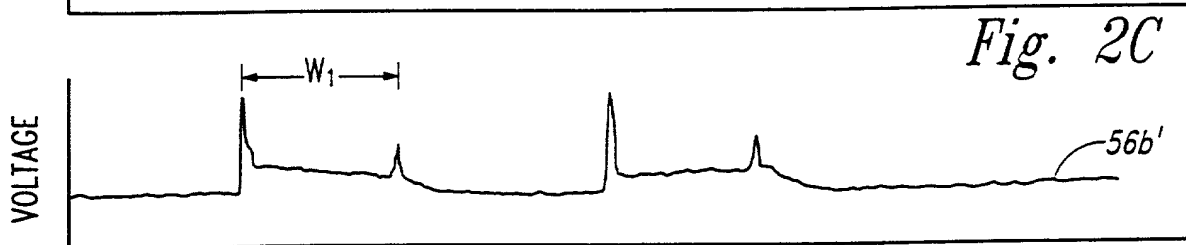
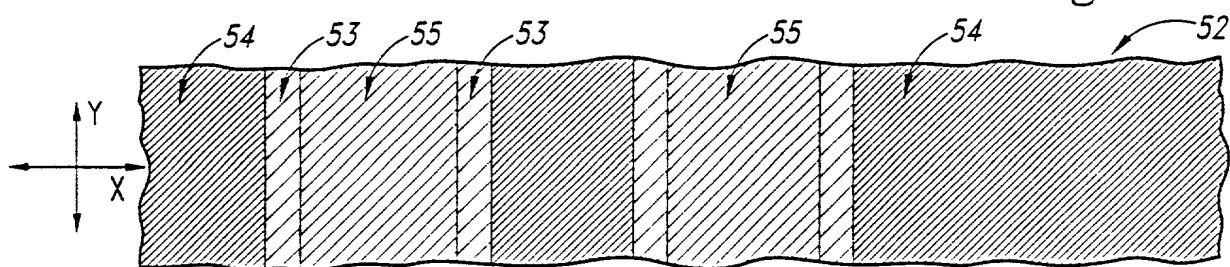
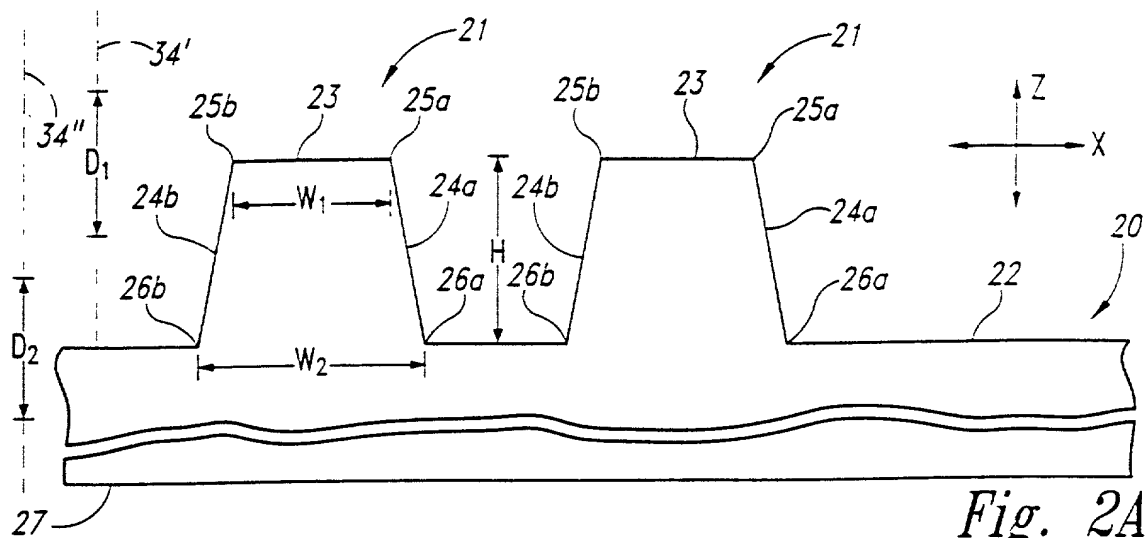
82. The method of claim 73 wherein the first electron flow is emitted by the feature when the first electron beam impinges thereon, and the step of measuring the first flow includes measuring the flow of emitted electrons.

METHOD AND APPARATUS FOR MEASURING  
FEATURES OF A SEMICONDUCTOR DEVICE

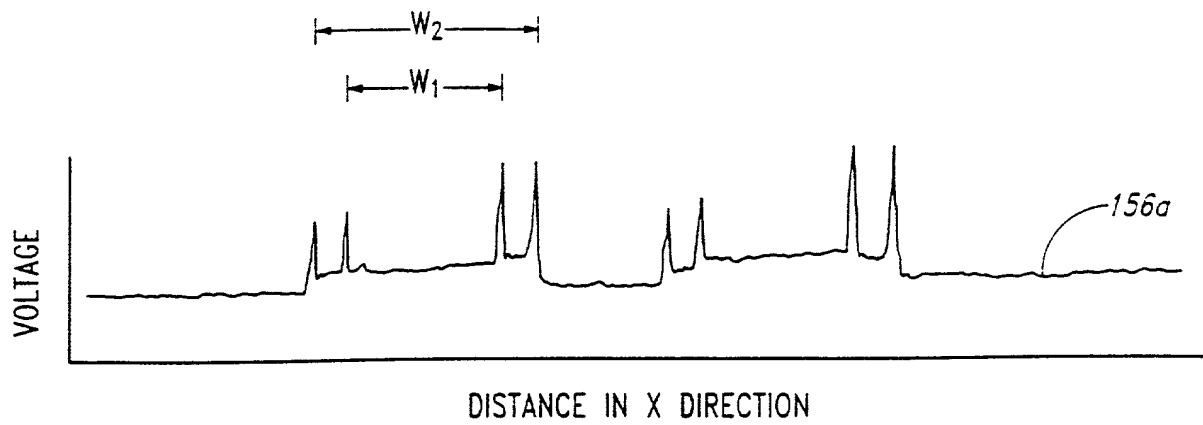
ABSTRACT OF THE DISCLOSURE

A method and apparatus for measuring the dimensions of features on the surface of a semiconductor device. The method may include passing a first electron beam having a first depth of focus over the semiconductor device and passing a second electron beam having a second depth of focus over the device. Electrical signals generated by the two electron beams may be analyzed singly or in combination to determine the lateral or vertical dimensions of the features at one or more positions relative to the surface of the semiconductor device. In one embodiment, the first and second electron beams are generated sequentially from a single electron gun. In another embodiment, the first and second electron beams are generated sequentially or simultaneously by either two separate electron guns or a single electron gun positioned proximate to two separate electron beam ports.

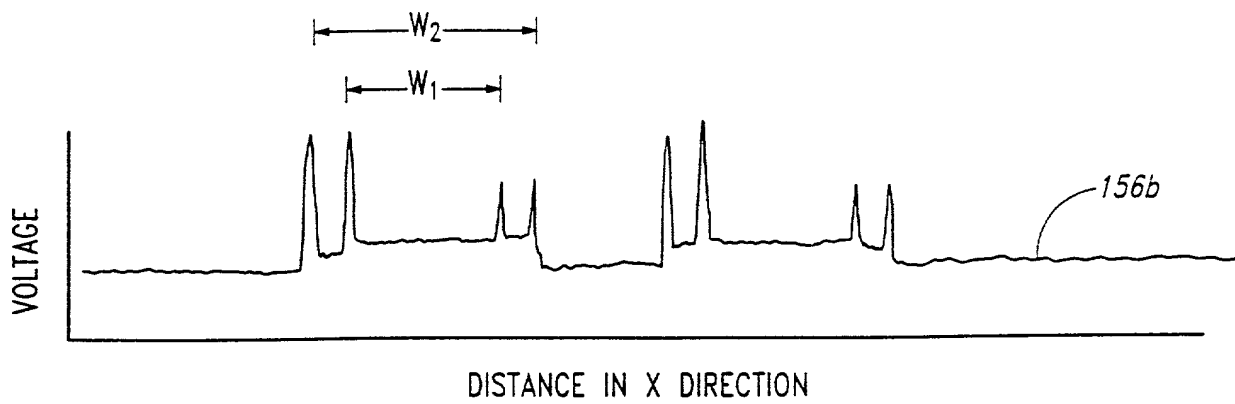




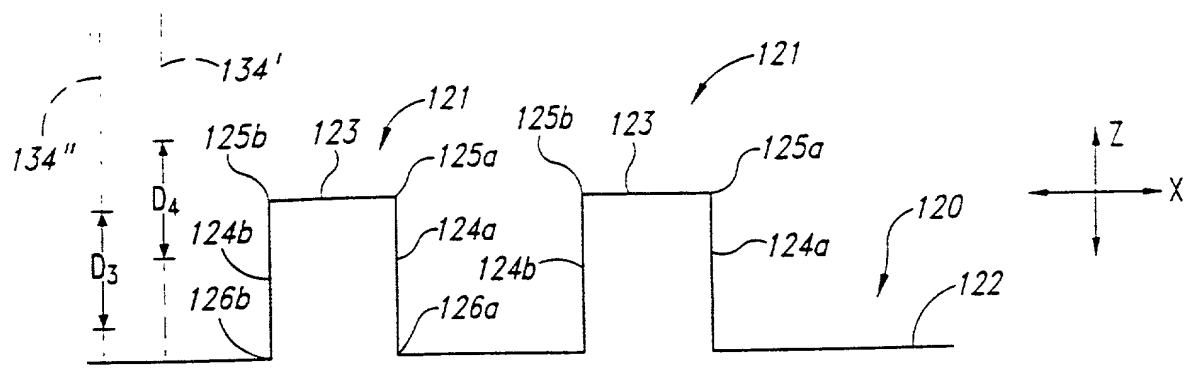
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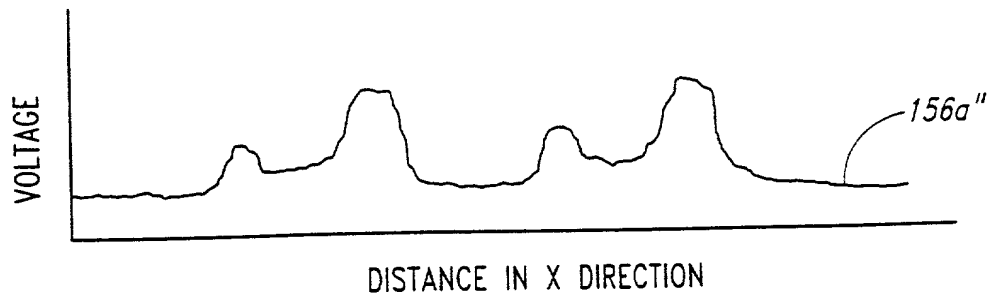
*Fig. 3A*



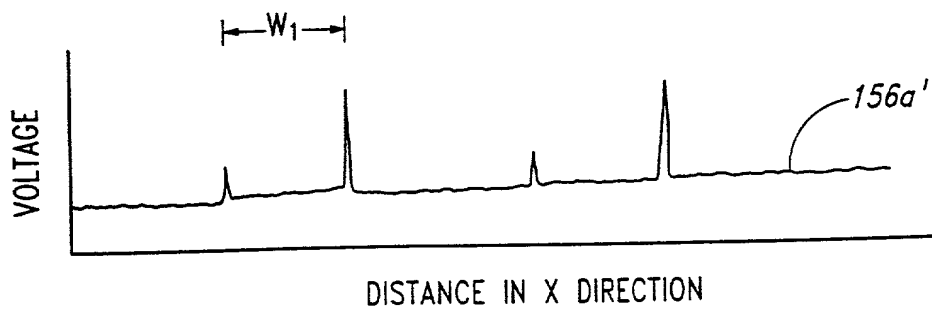
*Fig. 3B*



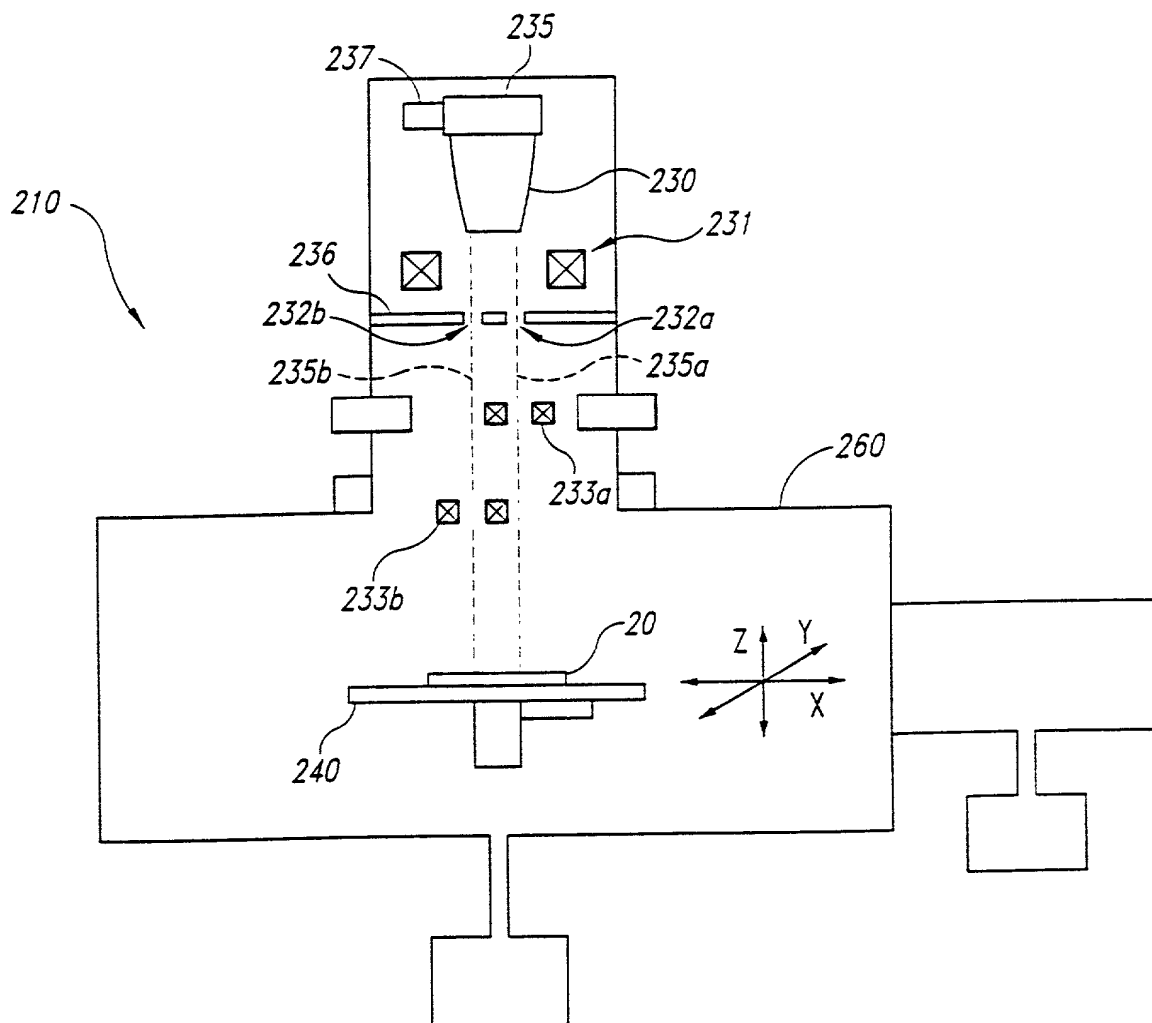
*Fig. 4A*



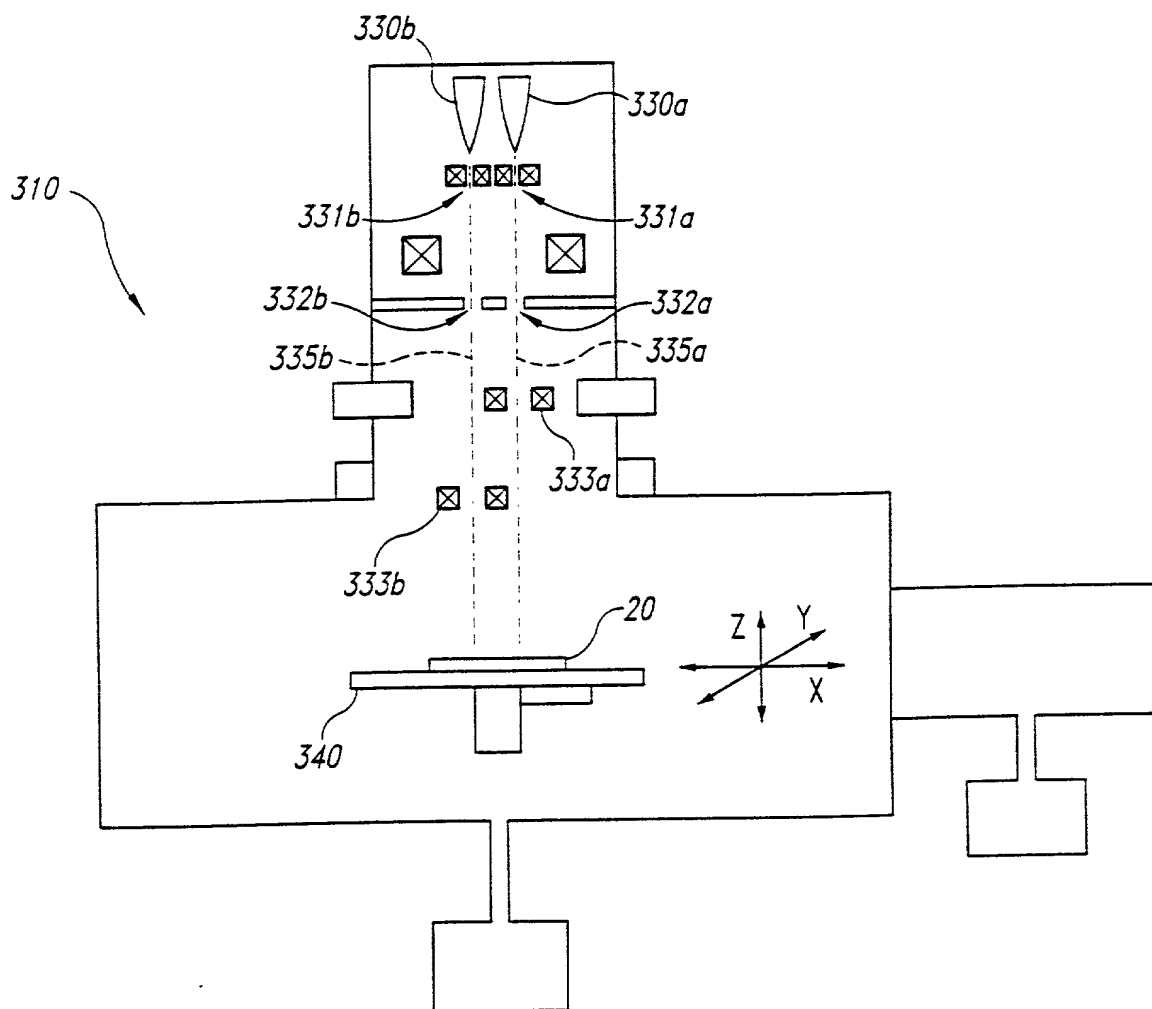
*Fig. 4B*



*Fig. 4C*



*Fig. 5*



*Fig. 6*



## DECLARATION

As the below-named inventors, we declare that:


Our residences, post office addresses, and citizenships are as stated below under our names.

We believe we are the original, first, and joint inventors of the invention entitled "METHOD AND APPARATUS FOR MEASURING FEATURES OF A SEMICONDUCTOR DEVICE," which is described and claimed in the foregoing specification and for which a patent is sought.

We have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to herein (if any).

We acknowledge our duty to disclose information of which we are aware which is material to the examination of this application in accordance with 37 C.F.R. § 1.56(a).

We further declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that the making of willfully false statements and the like is punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and may jeopardize the validity of any patent issuing from this patent application.


  
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Date 5-20-98

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## PATENT

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants : Douglas Do; and  
 Jeff Johnson  
 Filed : Concurrently Herewith  
 For : METHOD AND APPARATUS FOR MEASURING FEATURES  
 OF A SEMICONDUCTOR DEVICE

Docket No. : 660073.645

Box Patent Application  
 Assistant Commissioner for Patents  
 2011 Jefferson Davis Highway  
 Washington, DC 20231

ELECTION UNDER 37 C.F.R. §§ 3.71 AND 3.73 AND POWER OF ATTORNEY

The undersigned, being Assignee of the entire interest in the above-identified application by virtue of an Assignment filed concurrently herewith, hereby elects, under 37 C.F.R. § 3.71, to prosecute the application to the exclusion of the inventors.

Assignee hereby appoints RICHARD W. SEED, Registration No. 16,557; ROBERT J. BAYNHAM, Registration No. 22,846; EDWARD W. BULCHIS, Registration No. 26,847; GEORGE C. RONDEAU, JR., Registration No. 28,893; DAVID H. DEITS, Registration No. 28,066; WILLIAM O. FERRON, JR., Registration No. 30,633; PAUL T. MEIKLEJOHN, Registration No. 26,569; DAVID J. MAKI, Registration No. 31,392; RICHARD G. SHARKEY, Registration No. 32,629; DAVID V. CARLSON, Registration No. 31,153; MAURICE J. PIRIO, Registration No. 33,273; KARL R. HERMANN, Registration No. 33,507; DAVID D. McMASTERS, Registration No. 33,963; ROBERT IANNUCCI, Registration No. 33,514; MICHAEL J. DONOHUE, Registration No. 35,859; CHRISTOPHER J. DALEY-WATSON, Registration No. 34,807; STEVEN D. LAWRENZ, Registration No. 37,376; ROBERT G. WOOLSTON, Registration No. 37,263; ELLEN M. BIERMAN, Registration No. 38,079; BRYAN A. SANTARELLI, Registration No. 37,560; CAROL NOTTENBURG, Registration No. 39,317; CRAIG S. JEPSON, Registration No. 33,517; PAUL T. PARKER, Registration No. 38,264; JOHN C. STEWART, Registration No. 40,188; ROBERT W. BERGSTROM, Registration No. 39,906; DAVID W. PARKER,

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Please direct all communications to:

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Pursuant to 37 C.F.R. § 3.73, the undersigned duly authorized designee of Assignee certifies that the evidentiary documents have been reviewed, specifically the Assignment to MICRON TECHNOLOGY, INC. filed concurrently herewith for recording, a copy of which is attached hereto, and certifies that to the best of my knowledge and belief, title remains in the name of the Assignee.

MICRON TECHNOLOGY, INC.  
ASSIGNEE

DATE

July 10, 1998

Michael L. Lynch  
Chief Patent Counsel

Enclosure:

Copy of Assignment